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Various Aspects of Bollard Pull Tests and Analysis of Test Results

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The static force exerted on a hawser at zero ship speed by a vessel, otherwise known as the bollard pull, is one of the key performance indicators of Tugs, Anchor Handling Tugs (AHTs) and Anchor Handling Tug Supply Vessels (AHTSVs).The value of bollard pull is considered critical as it defines the functionality and performance of the vessel. When a company decides on chartering a vessel, a definite prerequisite considered is the value of the bollard pull. The value may be obtained via three ways: calculations, model-testing, and full-scale trials. The latter is often used officially to certify the vessel's bollard pull rating, with the presence of the vessel's owners, surveyors, and any other third parties. The tests and trials follow a set of guidelines provided by classification societies but do not have a standardized set of rules. Therefore, disagreements often arise over the results of such tests and trials. Tests are often carried without any load cells measuring the shaft power to ascertain the brake horsepower (BHP). Simply, engine rpm/ rating is used to fix the 100% maximum continuous rating (MCR) which often in the range of 105–108% MCR. Some of the parties involved in certifying the correct bollard pull tests (BPTs) do not even understand what is all about the bollard pull. Everybody is looking for a higher figure for the bollard pull on the certificate when the reality is different. The author examines and discusses the broad spectrum of factors that affects the "true" value of the bollard pull and explains why such a standardized set of mandatory BPT and the trial code is deemed necessary. The author also presents some of the interesting BPTs data to show the differences in various ways of conducting BPTs.

Keywords: Bollard pull; test and trial code; tugs; offshore support vessels; AHTs; AHTSVs; shaft power; engine MCR; instrumentation; classification societies; vessel performance

1. Introduction

The bollard pull (BP) is the zero speed pulling/pushing capability of a vessel, i.e., Tugs, Anchor Handling Tug (AHTs), Anchor Handling Tug/ Towing Supply Vessel (AHTSVs), trawlers, etc. It is considered as one of the key practical performance indicators of the above-mentioned vessels, measuring the usefulness of the vessel in a stranding scenario or in holding large vessels such as tankers or towing a rig.

Such bollard pull tests (BPTs) are conducted to ensure the performance of the vessel upon delivery. The test is witnessed in the presence of the International Classification Societies (CS) surveyors representing the classification society, the owners' representatives of the vessel, engine and propeller manufacturer, representatives from the shipyard, and people who have partaken in the construction of the vessel. The BPTs have a significant impact on the performance indicator of Tugs, AHTs, and AHTSVs.

It is so because, often, ship owners/ship operators would use the value of the bollard pull certification as a selling point of the vessel. The higher the value, the higher the weight the vessel can tow. Therefore, the value of the bollard pull becomes a key performance indicator of the vessel. Bollard pull is critical to ship owners/ship operators so much, so that the value of the bollard pull is one of the contractual items to be met during the contractual delivery of the vessel.

However, there are no stringent rules stipulated by classification societies for the conduct of a BPT. What are given is usually recommended guidelines for the conduct of the test, which is not specific enough to provide a standardized and identical method of testing.

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Improper method of testing would result in inaccurate values of recording the bollard pull. Often, such values are overquoted. One such possibility of bollard pull being overquoted is when during the conduct of such tests, the engine maximum continuous rating (MCR) is set to more than 100%, to obtain a higher value of bollard pull. Such scenarios might cause conflicts with operational safety such as the stability during towing and anchor handling. What is lacking right now in the industry, is that, is the measurement of the shaft horsepower (SHP) power to establish the brake horsepower (BHP) at 100% MCR. Certain terms must be defined properly, to formulate a standardized set of BPT procedure.

Firstly, it is important to understand the general procedure of a BPT and trial. A suitable test site is chosen, which is referred to as a basin, with a bollard pull testing facility. The bollard pull testing facility is certified to conduct BPTs and trials of up to a set value of bollard pull.

There would be two sections of the hawser: one of the sections connects the bollard and the dynamometer together, and the other section connects the dynamometer and the towing hook/towing drum, which is attached to the towing drum and winch, onboard the Tug/AHT/AHTSV.

Next, there would be different bollard pull terms used. Such terms should also be defined appropriately (Steerprop 2001):

1) Continuous Bollard Pull—it is the sustainable static pull with the vessel's engines, running at the engine maker's recommended MCR. The average value of the pull is taken over a specific period, usually from 5 to 10 minutes. If the readings are taken at 30-second intervals, the Continuous Bollard Pull is the average of all the readings over the specific period.
2) Maximum Static Bollard Pull—it will have a higher value than the Continuous Bollard Pull as it takes the highest value of the period of 30-second intervals. Subsequently, the highest average values of two consecutive periods are taken.
3) Maximum Bollard Pull—it is the single highest measured value, which is achieved when the engines are running at an overloaded condition (e.g., 110% MCR) is achieved for very short periods without causing damage to the engines. It is significantly higher than the Continuous Bollard Pull and therefore should not be referred to as the usual "Bollard Pull."

2. Aim and objectives

There are two main aims. The article aims to assess critically the guidelines provided by different classification societies and to formulate a standardized set of general guidelines most suitable for the marine and offshore industry.

The other is the collection of data of BPTR and to analyze those data to find the various aspects of bollard pull test results (BPTRs).

To achieve the purpose, the following objectives are established:

1) to define the different types of bollard pull and describe how significant is the bollard pull value critical in the marine and offshore industry being used as a functionality indicator of a vessel.
2) to list and explain the different factors, (e.g., the propeller, the aft hull shape, etc.) that affect the value of the bollard pull.
3) to compare and identify the guidelines used by the classification societies used during the conduct of a BPT and hence, listing the commonalities and differences.
4) to do a research on the comparison of the guidelines used by the classification societies, and therefore, formulate a set of general guidelines mostly appropriate for the marine and offshore industry.
5) to produce a number of standard checklist documents, which are to be used during a BPT.
6) to collect data of full-scale BPTRs and categorize those data and analyze to see the bollard pull trend as well as an anomaly in different sets of measurements.

3. Methodology

For this subject, the targeted vessels are mostly Tugs, AHTs and AHTSVs. Such vessels go through the conduct of BPTs. A flowchart of how the aim of "How BPTs are done?" is achieved is shown in Fig. 1.

The key factors that affect the value of the bollard pull are first identified. Such factors include the propulsion power and propeller design, aft body hull form design and nozzle design. Adjustments and improvements can be done to the factors during the design stage of the vessel to ensure the optimal bollard pull value.

Several recognized bodies such as International Maritime Organization (IMO 1998) and International Towing Tank Conference (ITTC 2011) have their sets of guidelines, where the classification societies would then make certain changes to accommodate to their respective classification societies.

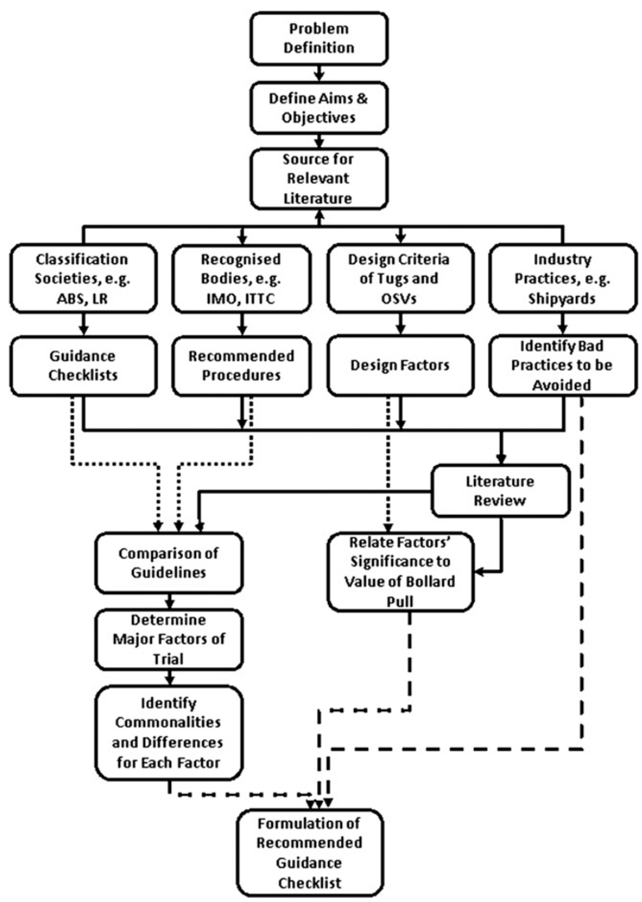

Fig. 1 Work plan flowchart

Shipyard practices are also noted. Each shipyard would have slightly different procedures as compared with the rest. Such differences might be slight, but it might be critical to the reliability of the accuracy of the test results.

British Ship Research Association (BSRA 1965) published a Code of Procedure for Bollard Trials of Tugs, which stated the high importance of preparation and calibration for the test, where failure to comply would significantly affect the results of the bollard pull.

Guidelines from major CS are also obtained. Such guidelines provide a comparison between different classification societies. The above differences and similarities are tabulated in the table for easy comparison and referencing.

Noting the key factors in performing a BPT, the detailed formulation for each factor is done to ensure a close to an ideal test is performed. The formulation was then compiled.

With the above steps performed, the final wording of guidelines in the form of guidance checklist recommended for use for BPTs and trials can then be formulated accordingly so as to provide a safe yet accurate procedure for testing.

4. Definition of bollard pull

The bollard pull of a vessel is defined as the tractive force of a Tug, which can be expressed in metric tonnes (tonne) or kilo Newtons (kN) (Zahalka 2012).

The test is conducted at zero forward speed; therefore, the wake (w) and relative rotative efficiency (η_R) do not apply. It is only the thrust deduction coefficient (t) that accounts for the interaction with the hull of the vessel.

At zero forward speed, the propeller would induce high axial and tangential velocities. This results in the flow through the propeller disc to be accelerated and thus creating a strong current, a heavy loading for the propeller and rudder.

Sometimes, the propeller may cavitate as ventilation occurs and the air is sucked in from the free surface. When this happens, the value of the bollard pull would, therefore, be inaccurate (ITTC 2011).

Simple rules have been used to relate the value of the bollard pull to the power installed on the vessel as estimations. Such approximations (Zahalka 2012) for the calculation of the bollard pull from the BHP of a Tug are given as

$$\text{Fixed Pitch Pr opeller: (Free Wheeling)} = \frac{\text{BHP} \times 0.9 \times 1.10}{100}(t) \tag{1}$$

$$\text{Fixed Pitch Pr opeller and Kort Nozzle} = \frac{\text{BHP} \times 0.9 \times 1.20}{100}(\text{t}) \tag{2}$$

$$\text{Controllable Pitch Pr opeller:(Free Wheeling)} = \frac{\text{BHP} \times 0.9 \times 1.25}{100}(\text{t}) \tag{3}$$

$$\text{Controllable Pitch Pr opeller and KortNozzle} = \frac{\text{BHP} \times 0.9 \times 1.40}{100}(\text{t}) \tag{4}$$

Where BHP is at 100% MCR

The values that are obtained from the above approximations are to be regarded as rough estimates. This is because, with different propulsion systems, a different bollard pull can be achieved, even with identical engines with the same installed power.

The value of bollard pull is usually used as a performance indicator of a particular vessel. Therefore, the initial calculation of the bollard pull of a vessel should not differ too much from the value obtained during the full-scale test of the same vessel.

The value of bollard pull also helps 1) to calculate the preplanned towing speed, and 2) to provide sufficient power-reserve to ensure the safety of the tow when in unfavorable weather conditions.

5. Design factors affecting BP

The design of a Tug, AHT, and AHTSV is not only dependent on the different physical components, such as the propellers, rudders, and engines. The performance is also influenced by the interaction between the various elements. An example would be the interaction between the propeller and the nozzle.

From Fig. 2 (Nielsen 2010), it can be observed that the attainable value of the bollard pull heavily depends on power density. To achieve the optimal value of the bollard pull, the value of the power density should be as low as possible. To attain a low-power density, the diameter of the propeller should be designed such that it is the widest that the vessel is able to accommodate, and it is fully submerged in water in ballast condition.

To achieve a high bollard pull, the vessels are usually fitted with twin screw with ducted controllable pitch propellers. It also gives them great maneuverability. It must also be understood that the installed power is not the only determinant that affects the value of bollard pull, where factors such as an optimized propulsion system and hull form design would also create an impact on the value of the bollard pull. Several design factors influence the value of the bollard pull which would be discussed.

5.1. Propulsion power and propeller design

The propellers are usually chosen by deciding on the power of the vessel, as the horsepower is proportional to the propeller diameter. Based on the expected operating conditions and propulsion power of the vessel, the diameter and the blades of the propeller are then designed appropriately.

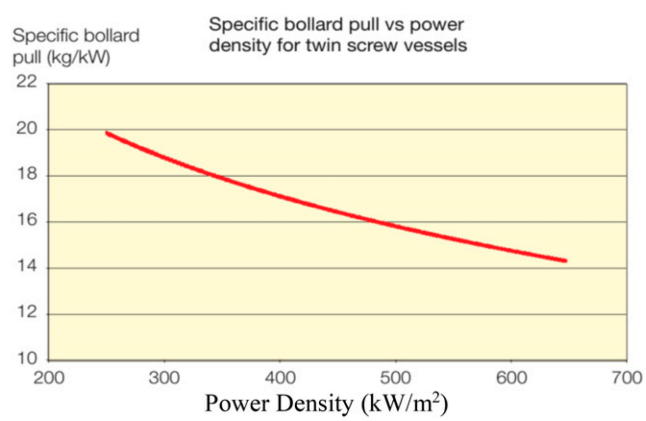

Fig. 2 Specific bollard pull versus power density

Factors such as the diameter of the propellers and r.p.m. of the shaft would affect the choice of a propulsion system used, as cavitation is a significant issue to be considered during the design of a propulsion system, specifically the propellers. For such Tugs and offshore support vessels, these are usually fitted with twin screw propulsion systems.

Factors such as open water propeller efficiency, cavitation, and vibration of the propeller are to be considered during the design of the propeller. The interaction between the nozzle and propeller are also critical during the design of the propeller. For most vessels that require maximum bollard pull, the shape of the blades tends to have wider chords at the tip of the propeller's blades, as shown in Fig. 3 (Lytewater 2009).

The skew of the propeller is also a defining factor for the design of the propeller. Given the right skew angle, the noise and vibration induced by the propeller can be suppressed.

5.2. Aft body hull form design

The water flow to the propeller, i.e., the wake field is influenced by the aft body hull form design. The lines of the aft hull form would, therefore, influence the thrust deduction coefficient.

$$t = 1 - \frac{T_{\mathrm{BP}}}{T_{\mathrm{PB}} + T_{\mathrm{NB}}} \tag{5}$$

Where, t is the thrust deduction factor, T_{BP} is the thrust of the bollard pull, T_{PB} is the propeller thrust in behind condition, and T_{NB} is the nozzle thrust in behind condition.

It can be seen that if the value of the thrust for the propeller and nozzle is reduced because of the thrust deduction coefficient, this will result in the thrust of bollard pull to be reduced too. It is caused by the interaction between the propeller and the nozzle, and the hull surfaces near to those.

To minimize the thrust deduction factor, proper design of the aft hull lines should be done. The shaft that the propeller is attached to should also be increased to the maximum wherever possible. It would then reduce the value of the thrust deduction factor to a minimum.

It should be noted that the wake coefficient for the design is also an important factor. However, because of the conduct of the BPT at zero speed, there is no effect of wake present.

5.3. Propeller nozzle design

A nozzle is a propeller shroud encircling just outside the propeller's tips. Including a nozzle in the design of the vessel would increase the thrust produced by the propeller. The effect of the nozzle is based on the hydrodynamics effect of pressure and velocity, where the thrust of water that passes through the nozzle is accelerated further.

Fig. 3 Kaplan propeller

Alignment of the nozzle during installation is also critical as it would affect the bollard pull. Nozzle alignment requirements would reduce the risk of misalignment during the installation process.

6. Key factors affecting BPTs

To ensure that the vessel achieves the optimum performance during a BPT, several factors are to be noted when conducting a test.

In an ideal (imaginary) BPT (Dev 2013), the following criteria are to be met:

1) lower and straight hawser (no sag and no angle)
2) larger water depth (three to four times draught with a minimum of 50m or more).
3) minimal current (<0.5 knots)
4) minimal wind (<0.5m/s)
5) good trim and sufficient draught for propeller immersion

Therefore, the key factors that affect the BPT are then determined:

1) environment
2) measurement and instrumentation
3) vessel condition

The BPT is supervised by the surveyors of CS, which then certify the vessel, the value of the measured bollard pull.

However, the guidelines of the classification societies differ in various ways. Therefore, the comparison is made between the guidelines stipulated by the different classification societies.

The different classification societies that would be used in the comparison later would include:

1) American Bureau of Shipping (ABS)
2) Bureau Veritas (BV)
3) Det Norske Veritas (DNV)
4) Germanischer Lloyd SE (GL)
5) Lloyd's Register (LR)
6) Registro Italiano Navale (RINA)

It is to be noted that although DNV and GL have recently merged to form DNV-GL, the guidelines are obtained prior from individual classification societies for comparison purposes. The comparisons for each factor stated above are then tabulated in a tabular form in Appendix A.

6.1. Environment

BPTs are usually conducted in areas where dock walls are present. With the presence of dock walls, the propeller wake from the propeller/s would cause a buildup of circulation. This buildup of circulation would result in a maximum bollard pull obtained too early in the course of the test, and drop when the test is prolonged. Such BPTRs obtained would not be an accurate representative of the service condition of the vessel, as the vessel would not remain in a particular position for such a long period of time to create such a significant amount of circulation during operation.

To reduce the impact of circulation on the effect of the BPTRs, the position of the vessel should be placed such that it is clear of any walls, and the propeller wake is given a clear run. RINA (2011) recommends the vessel to be positioned at 60° in respect to the pier. An example of such position is where the wake can run to either side of the bollard as shown at A of Fig. 4.

Results of model-tests (BSRA 1965) have shown that the influence of the dock wall is reduced when the depth of water is increased. Therefore, it should be known that the deeper the water, the results of the BPT would be more accurate. The distance between the vessel's stern and the dock wall should, therefore, be adequate if the available depth of water is limited.

Further positions for a BPT can be observed in Fig. 5.

Various classification societies including DNV (2011), RINA (2011) and GL Noble Denton (2010) further recommend that the distance should not be less than 100 m. The additional length of the hawser should be considered as the position of the towing hook on the vessel which would influence the total length of the hawser. The inclination of the hawser between the bollard and the towing hook should be kept to a minimum so that the horizontal component of the pull would then be measured accurately by the load cell.

BPTs are to be carried out in calm weather to reduce the effects of currents and winds as this would cause errors in the measurements. However, ABS (2012) allows the possibility of using correction due to bad weather conditions. It should not be allowed as the test would provide erroneous results.

It should be noted that the maximum value is recorded when the hawser is directly over the vessel's stern. The vessel would yaw upon the conduct of the test, and the angle of yaw becomes excessive, it would cause a considerable drop in the value of the pull. In such cases, the test should be repeated, with the angles of yaw recorded.

To ensure that the hawser is safe for use, it should be provided with a certificate, stating the breaking strength, material, and other relevant particulars of the hawser. Attached to the hawser includes equipment such as the winch and the towing hook. Such equipment should also be provided with a certificate to facilitate the conduct of the test.

During the conduct of the BPT where the vessel starts to sheer violently, it may cause a high pull value, in which the measured values should be ignored. Then the tests need to be repeated for accurate results.

6.2. Measurement and instrumentation

It must be noted that the conditions of the BPTs are unlikely to produce readings that are completely steady. In this case, there is a need to obtain mean values for analysis.

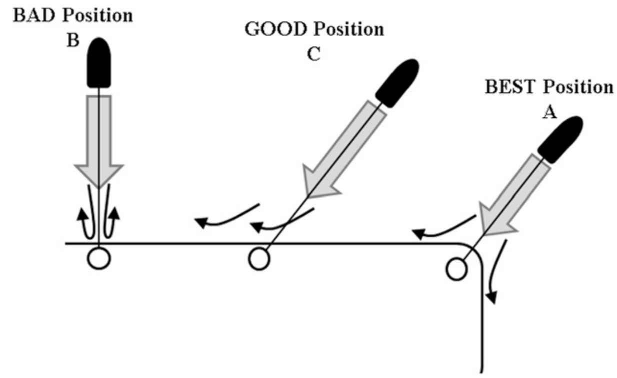

Fig. 5 Best, good, and bad positions for a BPT

The measuring instrument can either be a mechanical or an electrical load cell. Furthermore, the load cell must be provided with a calibration certificate, as requested by all classification societies conducting the test. It would then be ideal to provide the calibration being performed in the horizontal position because of the nature of usage during the test. The accuracy of a load cell differs for different classification societies.

An autographic recorder is to be included during the conduct of the test, as seen in the comparison in Appendix A. The recorder would then be able to produce the continuous record of the pull. It would make the analysis of results more accurate. However, if it is not possible to provide one, BV (1986) and GL Noble Denton (2010) recommend consecutive readings to be taken at 20 and 30 seconds, respectively.

The bollard pull should be taken on the vessel's towing hook, with the load cell located either next to the towing hook or near the bollard ashore (later preferable).

If the load cell is placed near the bollard ashore, arrangements should be made for the movement of the load cell for it to move freely. It would then allow alignment between the cable and the load cell in the event when the vessel sheers from one side to another. It would, therefore, ensure that the load cell measures only the horizontal component of the pull. An example of such provision would be mounting the load cell on a trolley as shown in Fig. 6 (BSRA 1965).

It is necessary to obtain the power developed by the shaft that corresponds to the respective value of bollard pull. A torsionmeter should be utilized to obtain the shaft power. By adding the considerable losses during transmission and the shaft power, it should give an appropriate value of the engines' BHP @ 100%

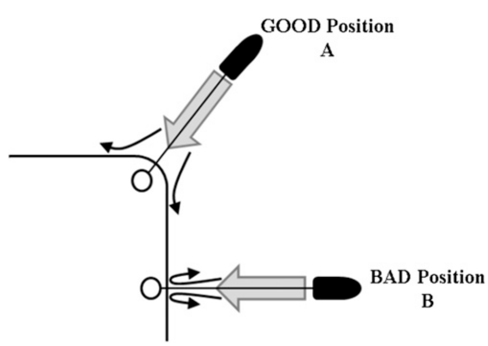

Fig. 4 Good and bad positions for a BPT

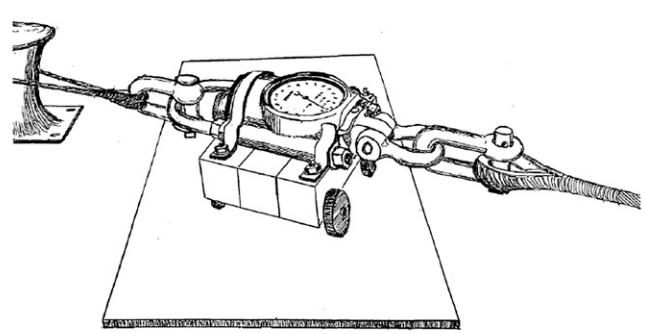

Fig. 6 Load cell mounted on trolley for alignment with cable

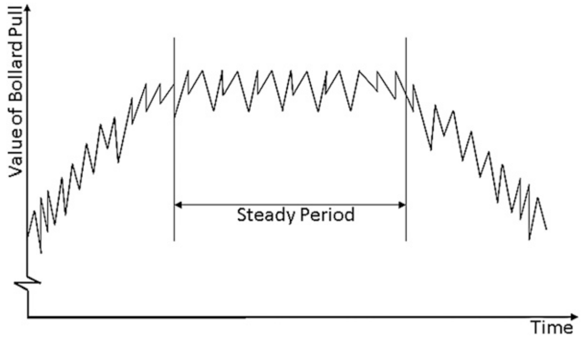

Fig. 7 Graph of value of bollard pull against time

MCR, which should be at 100%. It should therefore ensure that the engine is running at the manufacturer's recommended rated power at 100% MCR.

6.3. Vessel condition

The vessel condition is expected to be in the same condition during the normal operation. Therefore, the requirements comprise of conditions of the vessel during normal operation.

The condition of the vessel is also critical in the conduct of the BPT. The vessel must be evenly keeled or trimmed to intended normal operations during the conduct of the test. It is also recommended that the vessel is ballasted to the condition where it is supposed to operate.

The rudder angle must be kept to zero during the entire test, as any steering that will result in a drop is BPTRs. Equipment used during the test should also be the same during the use of actual service. It must be noted that any auxiliary equipment driven by the main engine(s) or propeller shaft(s) during normal operations should also be connected during the test.

All classification societies require that the main engine(s) should be running at a manufacturer's recommended MCR and should not be exceeded. ABS (2012) recommends that the engine temperatures are maintained steady during the test.

Communication between the party onshore and the party onboard the vessel should be present. This form of two-way communications should be reliable and consistent, by means of possibly very high frequency (VHF) radio or a telephone connection.

7. Analysis of BPTRs

Given that the results are recorded continuously using an autographic recorder, the results would be similar to the graph as seen in Fig. 7. It can be observed that there is an initial increase in values, during the build-up of engine revolutions, followed by a period where the results reach a plateau and steady, and finally a drop because of the circulation of water induced by the stagnant position of the vessel.

The steady period as seen in Fig. 7 indicates that there is a repetitive oscillations occurring. This period usually lasts from 10 to 20 seconds. The oscillations are mainly caused by the movements of the rudder for keeping the vessel in her position.

If the test is done without an autographic recorder, continuous monitoring should be observed, and values of the maximum and minimum pull should be recorded every 30 seconds. The values of the results are to be recorded in a tabular form as shown in Table 1, as part of the report. Note that the last column of the table requires the mean pull value for previous 10 readings, in other words, an average of 5 minutes is taken.

As stated by BSRA (1965), it is recommended to plot the values of the Mean Bollard Pull against the value of the engine revolutions squared correspondingly, as shown in Fig. 8.

As the torque coefficient for the propeller remains constant for 100% slip, the results would be proven consistent if the points plotted are lying approximately in a straight line, and the line should pass through the origin of the graph.

8. Data analysis of BPTs

To carry out various investigations about the actual BPTRs, a set of measured data (a sample of 86 numbers of tests) is used. The list is shown in Table 2. The names of the vessel have been replaced with arbitrary serial numbers. The list also shows the installed power in kW and the measured ahead bollard pull in tonnes.

8.1. Measured data and their analysis

The purpose of data analysis of the BPTRs is to furnish some guidelines based on actual measurements on full-scale tests, which are seldom available in literature. Such analyses and their outcomes help in preliminary estimation of the bollard pull of a vessel. The data analyses of results provide the following mainly:

1) a simple preliminary mathematical relation between the installed propulsion plant and the expected bollard pull.
2) a proof of generally higher bollard pull, when the BHP is based on engine rating (normally greater than 100% MCR) instead of establishing it through shaft power measurement.
3) an alternative mathematical relation using the specific bollard pull and the power density, which also takes into account the propeller diameter in predicting the bollard pull.
4) a rule of thumb that 100 BHP produces a bollard pull of about 1.25 tonnes is approximately verified.

Table 1 Record of BPTRs in a tabular form

	Bollard pull (Tonnes)			
Time of day (hours, minutes, seconds)	Maximum	Minimum	Mean	Mean pull for previous 10 readings
.	.	.	.	.

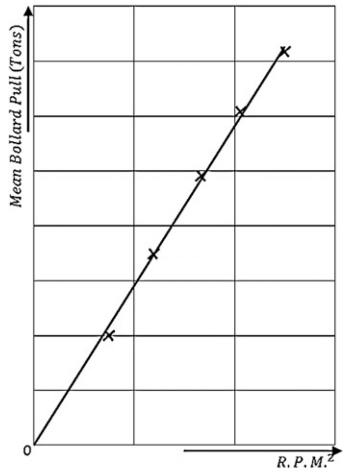

Fig. 8 Graph of mean bollard pull against R.P.M.[2]

5) the astern bollard pull is always less than the ahead bollard pull, i.e., Astern BP ≈ (0.8 to 1.0) x Ahead BP for vessels with aft azimuth propulsion drives.

In Fig. 9, it has been shown that it is quite likely that the relation between the measured bollard pull (tonnes) and the brake power (kW) shows an excellent linear fit with r^2 value almost equal to 0.98 showing the slope of about 0.162. In Fig. 10, an interesting difference is noted for the same set of data. Now the data are separated into two groups: one data where the shaft power is measured to find the BHP after adding the losses in bearings, gearboxes, etc. and the other set of data is where the shaft power is not measured; the BHP is just based on the engine rating. The practice of doing the latter in BPT is becoming a standard practice in most of the shipyards in South Asia, Southeast Asia, and East Asia. There could be a euphoric agenda here among all parties to achieve a maximum bollard pull number (gimmick or illusion) on the certificate. The BHP rating is used as 100% MCR, but in reality, it is much higher almost in the range of around 104–106% MCR. Surprisingly, the CS is not taking any serious note of it. The author cannot understand how one can calculate 100% MCR without having a proper shaft power measurement device. There are two main reasons for not doing it. The first reason is to save the cost of hiring a consultant to set up the shaft power measurement system, and the second reason is to achieve a so-called 100% MCR BHP. However, the industry is bit naïve without understanding the far-reaching implications of such a bollard pull number which will never be able to achieve in reality. Such practice of BPTs without shaft power measurement must not be accepted by any classification society so as not to jeopardize the operational safety of the vessel.

Figures 11 and 12 show the specific bollard pull (the bollard pull measured in kg divided by the total installed BHP in kW) as a function of power density (the installed BHP divided by the disc area of the propeller connected to the engine or a pair of engines). These graphs were produced to see the similar trend as shown in Fig. 2. Although Figs. 9 and 10 could give an indication of bollard pull based solely on the installed BHP, Figs. 11 and 12 will be more relevant and practical to use because it will take into account the effects of the propeller diameter along with the installed power on the expected bollard pull. It could be a better way of preliminary estimation of the bollard pull of a vessel. The author himself has experienced before. Once for an AHTSV, there should have been an easy target of getting 70 tonnes out of 5916 BHP, but it was a problem because the propeller diameter was not suitable rather undersize. An increase of another 100 mm would have a better sign, but sometimes, the commercial people do not listen to save cost and invite unnecessary risks.

Table 2 List of vessels, bollard pull and installed power in kW

Number	Col. 1	Col. 2	Number	Col. 3	Col. 4
1	40.2	2240	44	156.0	9000
2	49.2	2998	45	124.0	8120
3	49.2	2998	46	124.0	8120
4	51.5	2998	47	81.7	4920
5	49.5	3132	48	122.0	8120
6	49.4	3132	49	56.6	3730
7	51.0	3000	50	125.0	8120
8	51.9	3000	51	124.0	8120
9	35.8	2090	52	45.3	2646
10	198.0	13440	53	45.3	2646
11	35.6	2500	54	99.4	5940
12	213.0	13440	55	101.0	5940
13	212.0	13440	56	177.0	11040
14	98.0	5850	57	63.2	5280
15	211.0	13440	58	178.0	11040
16	209.0	13440	59	135.0	8000
17	61.5	3700	60	142.0	7920
18	60.4	3700	61	135.0	8000
19	98.7	5850	62	113.0	5940
20	212.0	13440	63	139.0	7920
21	61.3	3700	64	44.8	2646
22	68.0	4924	65	43.1	2646
23	66.8	4140	66	141.0	7920
24	64.9	4140	67	140.0	8000
25	68.2	4140	68	143.0	7920
26	52.6	3530	69	135.0	8000
27	166	9840	70	50.8	2998
28	45.5	2646	71	51.5	2998
29	46.3	2646	72	110.0	6972
30	158.0	9840	73	150.0	9000
31	100.0	6400	74	150.0	9000
32	72.0	5372	75	141.0	7920
33	141.0	9000	76	126.0	8190
34	159.0	8700	77	60.1	5280
35	45.5	2646	78	63.2	5280
36	45.0	2646	79	135.0	7920
37	135.0	8000	80	162.0	10736
38	45.6	2646	81	112.0	5940
39	44.8	2646	82	25.6	2424
40	136.0	8000	83	68.9	4000
41	71.4	4414	84	71.2	4000
42	72.8	4414	85	110.0	5940
43	43.5	2646	86	156.0	9000

Col. 1 and Col. 3 = ahead bollard pull in tonnes.

Col. 2 and Col. 4 = installed brake power in kW.

It is more or less an industry practice in bollard pull community that for a given power in BHP with an appropriately designed propeller, 100 BHP produces a bollard pull of about 1.25 tonnes, i.e., a standard bollard pull coefficient (t/100HP) (BPC_{100}) as 1.25 t/100HP. Based on the collected data, one of the analyses was done to verify this standard practice/rule of thumb. From Fig. 13, it is clearly seen that after analyzing all data; the

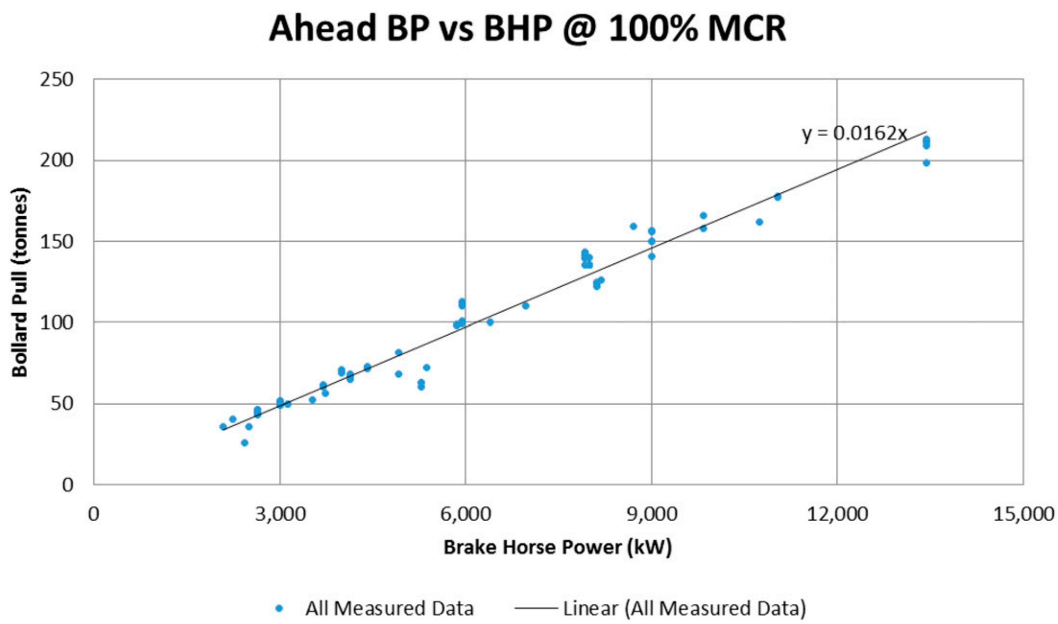

Fig. 9 Ahead bollard pull versus BHP at 100% MCR

mean curve is somewhat less than 1.25 tonnes per 100HP line (red color), i.e., a BPC_{100} of 1.21 tonnes/100HP. The measured data are again found above and below the datum line of 1.25 tonnes per 100HP. Hence, in Fig. 14, two lines were then drawn for data greater than 1.25 tonnes and for data less than 1.25 tonnes. These two lines now provide a reasonable range of the estimated bollard pull roughly between BPC_{100} of 1.21 to 1.27 tonnes per 100HP which result in an average of BPC_{100} as 1.24 tonnes per 100HP. So, the industry thumb rule/practice of using 1.25 tonnes per 100HP is somehow a justified value. In these two graphs, the author did not separate the bollard pull measured data based on whether the shaft horse power measured or not during the BPT. A larger data sample will only make all these statistical forecasts more accurate predictions.

In Figs. 15 and 16, some results of ahead and astern bollard pull measured data have been analyzed. From Fig. 15, it is observed that the measured astern bollard pull is always less than the ahead bollard pull except a few data where some opposite trends are noted. There could be some other reasons for having such few discrepancies. The astern bollard pull is always less than the ahead bollard pull except for thrusters which are below the baseline where both ahead and astern pull should always be the same theoretically as there is hardly any thrust deduction factor, e.g., for a tractor tug with two azimuth thrusters in front of the tug below the hull.

In Fig. 16, again the ratio of astern bollard pull to ahead bollard pull has been shown. It should remain theoretically below or equal

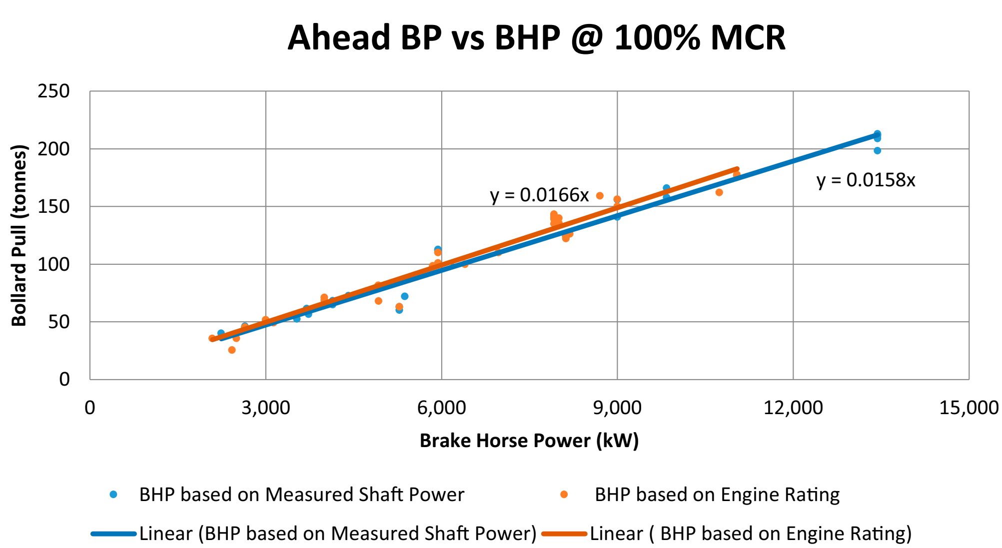

Fig. 10 Ahead bollard pull versus BHP at 100% MCR

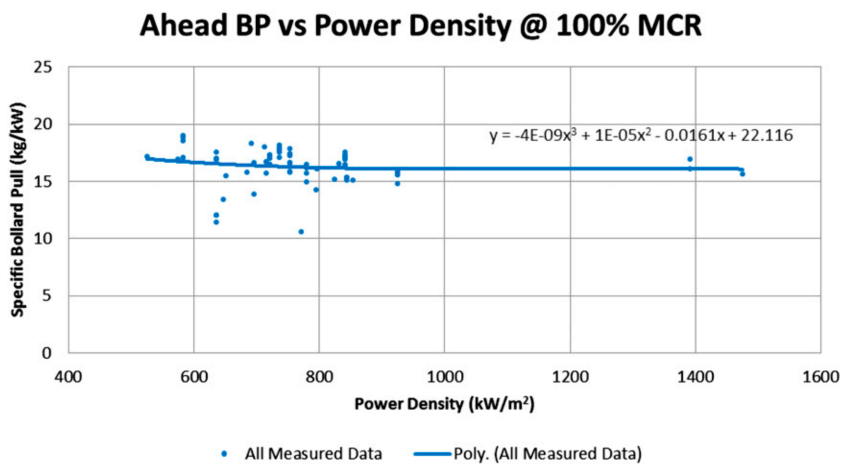

Fig. 11 Ahead bollard pull versus power density at 100% MCR BHP

to 1 but because of discrepancies in some measured data, some values are seen to be more than 1. It is clearly observed that the ratio varies from 0.8 to 1. For vessels, mainly tugs with azimuth stern drive, the value will be close to 1 if most of the thruster is below the baseline. However, if the thruster is above the baseline, the astern pull will be less and can be said around 0.8 times the ahead bollard pull. For vessels like AHTSVs, the astern bollard pull is almost 0.4 times the ahead bollard pull. It is mainly because of Controllable Pitch Propeller (CPP) propulsion with rudders behind.

9. Discussion

Upon comparison of the guidelines of the stated classification societies, critical parts of the rules are identified. The tabulated comparison of the directives/guidelines can then be found in Appendix A. The adoption and formulation of the standardized set of BPT code is found in Appendix B

A typical BPTR should then be provided to certify the vessel of the bollard pull value. Critical information and particulars are to be provided in the report. A set of recommended format is provided in Appendix C. The report is to be attached with the various forms used by the surveyors to record data during the test.

Required documents such as calibration certificate of the load cell and engine manufacturer recommendations for 100% MCR are also to be attached with the report upon submission to a classification society for verification.

Forms are created to provide convenience for surveyors for conducting the test. These forms can be found in Appendix D and E, where the forms are to be used for the engineers/surveyors onshore and on board the vessel, respectively.

Results have also shown that using a general rule to link the value of bollard pull to installed power would be very much inaccurate. It is because even with identical propulsion systems, vessels with different hull lines and propeller geometry would result in significant bollard pull results.

It is possible to estimate bollard pull, using numerical calculations or even model-testing, regardless of its accuracy. However, verifying the values of bollard pull is only certifiable by the classification societies by the means of full-scale testing.

To provide fair testing results, a uniform set of rules is to be used throughout all classification societies. In this connection, International Association of Classification Societies (IACS) can play a major role. Bollard pull is a performance very much related to the safety of operation like towing, anchor handling, etc. A wrong (misleading) bollard pull number on a certificate

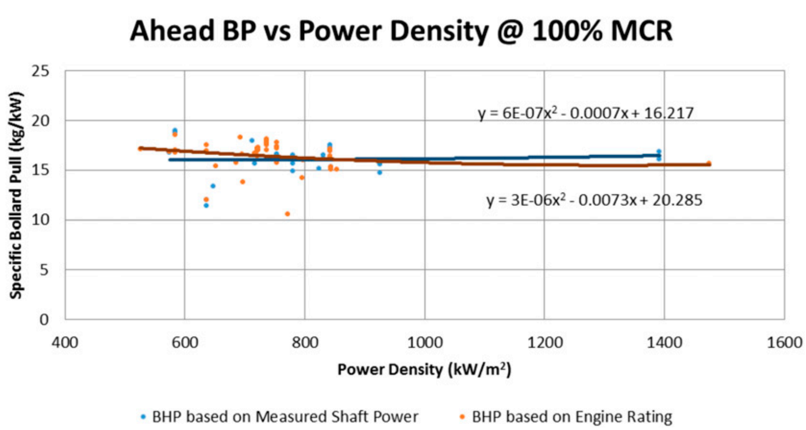

Fig. 12 Ahead bollard pull versus power density at 100% MCR BHP

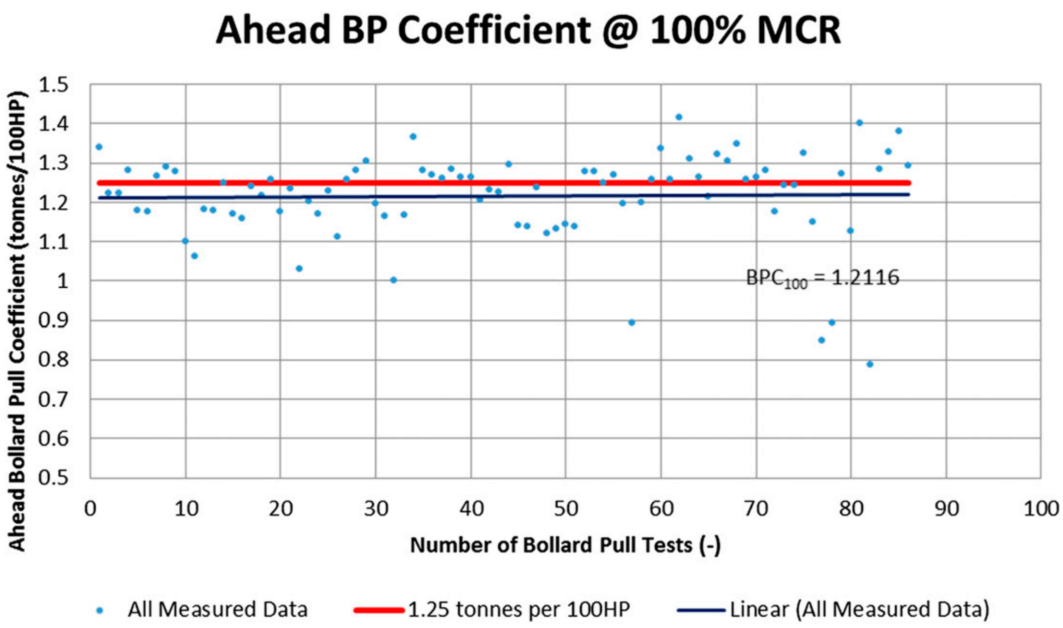

Fig. 13 Ahead bollard pull coefficient at 100% MCR BHP

can lead to a potential danger in real operational life of the vessel.

It is a practice for companies that conduct BPTs to use corrections upon experiencing poor weather conditions. However, such corrections are not allowed and would result in an inaccurate value of bollard pull. Therefore, this should not be allowed as it would compromise the stability of the vessel if the vessel were to operate beyond its capability. It would result in a breach of operational safety leading to unnecessary risks.

The data analysis of the regular BPTs indicates that some of the industry practices are entirely valid. It also suggests that conducting a test without the shaft power measurement and alternatively setting a 100% MCR number based on engine rating is either a gimmick or an illusion to the parties involved. The truth is that such bollard pull number on a CS certificate is entirely not factual. The shipyard, the owner and the CS surveyor should exercise a right spirit of accuracy and quality in conducting/witnessing such an important test which should establish an unbiased fact (reality).

10. Conclusions

Directives/guidelines are being provided across most notable classification societies.

However, it has been observed that the guidelines as recommended in the CS's guidelines are not as definitive as it should be. It might thus cause the results of the bollard pull to be erroneous.

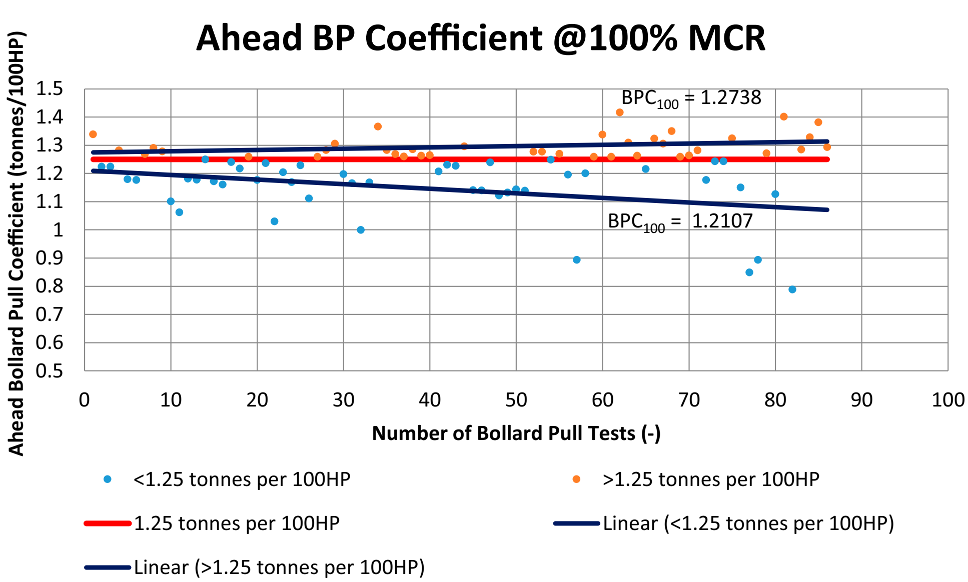

Fig. 14 Ahead bollard pull coefficient at 100% MCR BHP

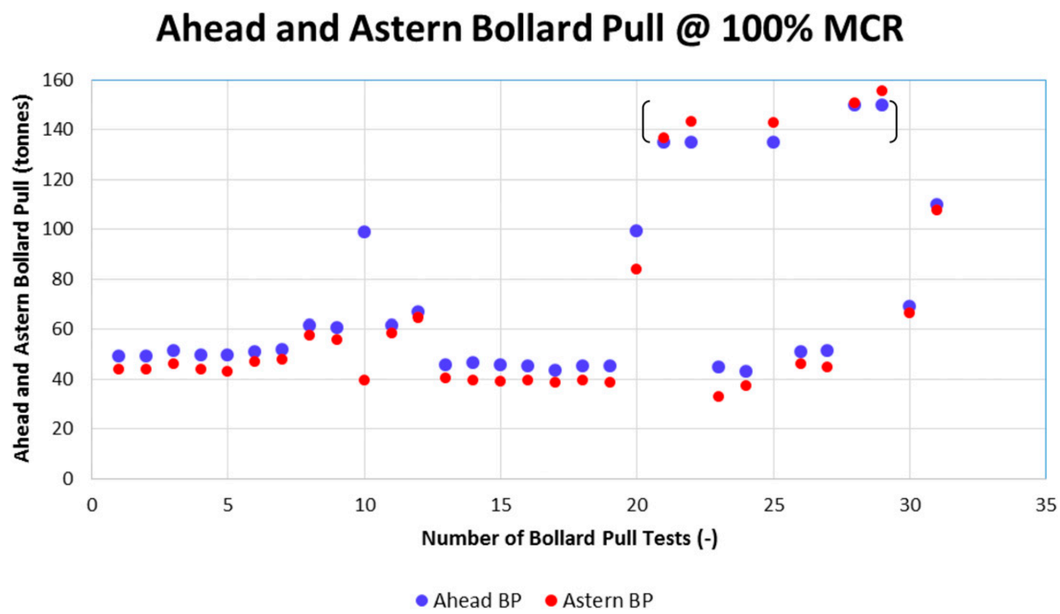

Fig. 15 Measured ahead and astern bollard pull at 100% MCR BHP

Therefore, it is necessary to ensure a standardized procedure to provide a true (fact) value of BPT. In turn, it would be a fair functionality indicator for vessels which are required to undergo the BPT and trial.

The literature related to the subject also revealed the importance of conducting the BPT to obtain full-scale results. It would provide the ship owners with a form of verification during the delivery of the vessel.

As much as model-testing and the numerical solution can provide a kind of an answer, it is unable to simulate the full-scale environment. Therefore, it is safe to assume that BPT on a full-scale basis would then be most accurate to act as a functionality indicator for Tugs, AHTs, and AHTSVs.

It is also to be noted that there are several similarities and, more importantly, differences, in the directives/guidelines of the different classification societies. One significant difference would be the values of accuracy required by the classification societies for the calibration of the load cell.

If possible, and feasible, the standardized code of procedure should be recommended to classification societies. With the uniform application of proceedings during the conduct of bollard pull, it is possible to create a fair environment for the certification for all BPTs for all types of vessels.

Most importantly, operational safety can also be assured if the conduct of the BPT is carried out appropriately, on a yearly basis.

Acknowledgment

The present work benefited from the input of Mr. Ong Hing Hui, Past BEng student at Newcastle University, who has done his final

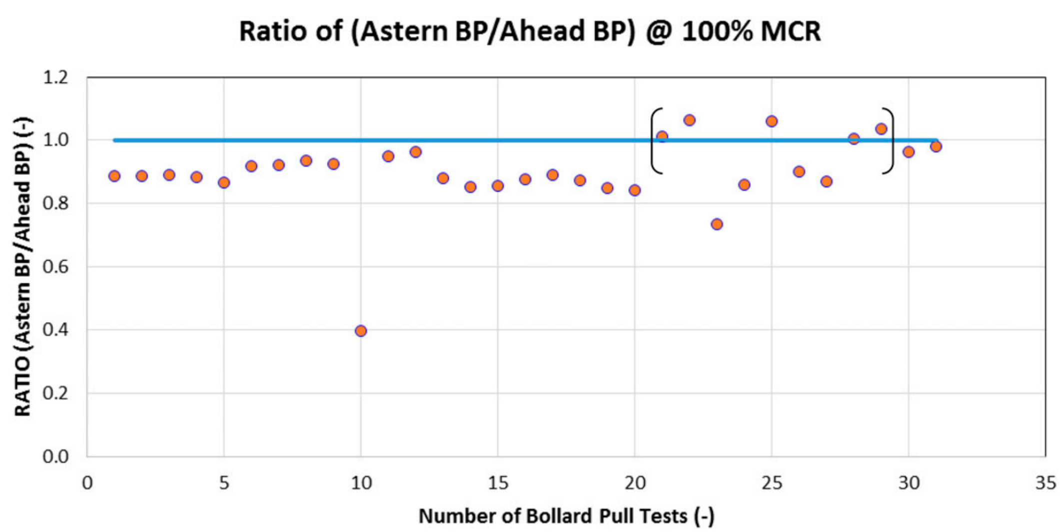

Fig. 16 Ratio of astern and ahead bollard pull at 100% MCR BHP

year project on a similar topic. The author is also grateful to Mr. Wei Gan, an ex-student of the University of Western Australia for compiling all the measured BPTs' data and produce initial graphs under the constant supervision of the author for almost 3 months. The author is also grateful to his classmate Mr. Makaraksha Saha helping to create the final graphs and review the article with some comments.

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Appendixes

Appendix A

Table 1 Comparison of rules between the different class societies: towline and location

		Location				
	Towline	Depth of water	Distance	Current	Wind	Sea State
American Bureau of Shipping	-	Depth of water under the keel at the test site should be of at least twice the draft at amidships.	Distance from the stern of the towing vessel to bollard should be at least two ships length.	If current exceeded 1 knot, correction should be done.	Wind speed should be 10 mph or less.	Sea condition should be calm.
Det Norske Veritas	Length of towline should not be less than 300 m, measuring from the stern of the vessel to the shore.	The water depth at the test site should not be less than 20 m.	Within a radius of at least 100 m of the vessel.	Current shall not exceed 1 knot in any direction.	The test shall be performed with a wind speed not exceeding 5 m/sec.	-
Bureau Veritas	The towing line used should be the normal equipment of the tug; 50 m for sheltered waters and sea and river towage, 100 m for sheltered waters towage, 300 m for deep sea towage.	A minimum ratio (depth under the vessel divided by the draft of the vessel) of 3; the water depth should not be less than 10 m.	Within a radius of at least 4 X Length from the vessel.	The stream speed should not exceed 1 knot in any direction.	Wind speed should not exceed 15 knots.	-
Lloyd's Register	-	Depth of water under the keel should be equal to twice the draught, with a minimum of 10 meters.	Open water ahead of the tug for an adequately safe distance.	Current speed at the test location should not exceed 0.5m/sec in any direction.	A maximum wind speed of 5 m/sec.	Sea condition should be calm.
Registro Italiano Navale	Minimum of 100 m.	At least twice the maximum draft with a minimum of 10 m. The minimum required water depth shall be ensured in the area around the tug within a radius of 50 m, which shall be kept free from obstacles for the duration of the test.	To be not less than four times the ship's lengths and, in any case, not less than 100 m. Tug to be positioned at an angle of about 60° in respect of the pier.	During the test, the speed of the current should not exceed 0.5 m/s.	During the test, the wind speed shall not be more than 5 m/s.	
Germanischer Lloyd SE	-	At least 20 meters within a radius of 100 meters of the vessel. If a water depth of 20 meters cannot be achieved at the test site, then a minimum water depth which is equal to two times the maximum draught of the vessel may be accepted.	The test location should be clear of any possible navigational hazards and underwater obstructions within a radius of 300 meters of the vessel.	Current should not exceed 0.5 meters/second from any direction.	Wind speed shall be less than 5 meters/second from any direction.	The sea condition should be calm.

Table 2 Comparison of rules between the different class societies: vessel

	Vessel			
	Trim	Vessel Condition	Machinery	Engine(s)
American Bureau of Shipping	Even keeled or trimmed to intended operating conditions.	Normal Ballast Condition, but no required to be down to summer load line.	-	Engine(s) should not be adjusted to operate in overload conditions. Engine temperatures should be at steady state during test run at MCR (certified horsepower per records).
Det Norske Veritas	At even keel or at a trim by stern not exceeding 2% of vessel length.	The vessel shall be at full ballast and half fuel capacity.	Propeller(s) fitted when performing the test shall be the propeller(s) used when the vessel is in normal operation. All auxiliary equipment driven by the main engine(s) or propeller shaft(s) should be in operation during the test.	Shall be run at manufacturer's recommended MCR.
Bureau Veritas	Should not exceed 4% of vessel's length and in accordance with normal operating conditions of the vessel.	The vessel should be in full ballast and fuel capacity.	The propeller(s) and nozzle(s) fitted during the test should be those fitted during normal operation. All auxiliary equipment driven by the main engine(s) or propeller shaft(s) should be in operation during the test.	The maximum continuous output recommended by the manufacturer of the main engine should not be exceeded during the tests.
Lloyd's Register	Comply with the intended operating trim.	Comply with the intended operating ballast condition.	All outfits must be in good condition and capable of exerting/ withstanding a load of not less than two times the anticipated Maximum Bollard Pull. It is then assumed that all equipment will be part of the tug's normal outfit. Propellers fitted when performing the tests should be those used during normal service.	The maximum continuous output recommended by the manufacturer of the main engine should not be exceeded during the tests.
Registro Italiano Navale	Even keel condition with a maximum stern trim not greater than the 2% of the vessel's length.	Heavy ballast condition with the fuel tanks filled to at least 50% of their capacity.	Equipment used during the test is to be part of the actual tug equipment during normal service. All auxiliary machinery driven by the main propulsion engine(s) or by the shafting line(s) during normal service are to be kept in operation throughout the trial.	Shall be kept at the manufacturer's recommended maximum continuous rating, on the basis of which the classification of the tug has been requested, throughout the BPT.
Germanischer Lloyd SE	As close as possible to the draught and trim under normal operating conditions.	As close as possible to the ballast conditions under normal operating conditions.	All the propellers and fuel installed and used during the test are to be the same as those used during intended operating conditions. All auxiliary equipment driven by the main engine(s) or propeller shaft(s) should be in operation during the test.	Shall be kept at the engine manufacturer's recommended maximum continuous rating (100% MCR) of the main engines, for a period of 10 minutes for continuous bollard pull, 110% MCR for 5 minutes for a maximum BPT.

Table 3 Comparison of rules between the different class societies: instrumentation

	Instrumentation				
	Load Cell	Calibration	Continuous read-outs	Position of Load Cell	Communications
American Bureau of Shipping	Fitted with swivels and torque insensitive. Maximum scale reading should be a minimum or equal to [Max. Cont. Total H.P. X 50 (LBS.)]	Should be calibrated and suitable for use in the horizontal position.	-	Should be located at the ashore end of the tow hawser.	A two-way voice communication should be provided between the vessel and shore station
Det Norske Veritas	Load cell used for the test shall be approved by DNV	Calibrated for at least once a year. The accuracy of the load cell shall be ±2% within a range of −10°C to +40°C and within the range of 25 and 200 tonnes tension.	The instrument giving a continuous read-out also a recording instrument recording the bollard pull graphically as a function of time shall both be connected to the load cell.	Load cell shall be fitted between the eye of the towline and the bollard.	A communication system shall be established between the vessel and the person(s) monitoring ashore, by means of VHF or telephone connection.
Bureau Veritas	Other methods of measurement for instance based on the readings on winch equipment (tension indicator, pressure gauge) may be accepted subject to compliance with accuracy requirements.	The cumulated accuracy of all the measuring equipment is 5% within a temperature range of −20°C to +40°C	Continuous read-outs and a recording of the bollard pull are recommended. If not possible, readings are taken every 30 seconds.	-	Recommended to have recording equipment ashore, and a reliable telecommunication system.
Lloyd's Register	Should produce continuous readout in numerical and graphical form. The instrument should be calibrated before each application by the Society or any other recognized authority.	Expected accuracy to be within ±2%.	The recordings of the dynamometer should be coupled with the recordings of the main engine output and shaft revolutions. The dynamometer could be of the form of mechanical load gauge or an electric load cell.	Incorporated within the towing wire system, be located at the shore line or on the tug.	-
Registro Italiano Navale	The use of electric load cell type measuring instruments is recommended insofar as they can be connected to the recording equipment easily	Of not more than 12 months before the date of the BPT. In temperatures between 0 and +40°C. Maximum deviation from the nominal value is not more than ±2%	Shall be able to provide a continuous reading of the tug pull and record the values measured either in digital format or by means of a graph.	Connected directly to the towline. Placed in proximity to the towing hook (on board) or to the pier bollard (ashore).	Necessary to provide an efficient two-way communication system between the tug and the shore personnel responsible for monitoring the pull measurements.
Germanischer Lloyd SE	The calibration certificate of the load cell should be provided prior the test date.	Calibration must be less than 6 months before the test. Accuracy of ±2% for the average temperature observed throughout the test.	An autographic recording instrument that gives a continuous read-out of the bollard pull should be connected to the load cell. Otherwise, the bollard pull is then the average value of the subsequent readings, recorded every 20 seconds intervals over the test period.	-	-

Appendix B

BPT guidance checklist
Project number: click here to enter a number. Certificate number: click here to enter a number

Description	Yes	No
1. General	☐	☐
a. A proposed test program shall be submitted b the testing.	☐	☐
b. The safe working load (SWL) shall not be less than 10% of the vessel's designed value of the maximum static bollard pull for every test equipment, fittings and any connection points ashore.	☐	☐
c. All machinery/equipment shall be approved by a competent body/bodies. All documents including relevant information regarding the vessel, machinery and equipment's certification, etc. shall be prepared and submitted to the relevant body/bodies responsible for conducting the BPT.	☐	☐
d. Before the test, ensure the documents addressed in item c. above shall be received by the relevant body/bodies conducting the BPT.	☐	☐
2. Location		
a. The water depth at the test location shall be at 3 to 4 times the vessel draught, with a minimum of 50 meters, within a radius of 100 meters from the vessel.	☐	☐
b. The test location shall be clear of navigational hazards and underwater obstructions such as submerged pilings, bulwarks, etc. within a radius of 300 meters from the vessel.	☐	☐
c. The current shall be less than 0.5 meters/second from any direction.	☐	☐
d. The wind speed shall be less than 5 meters/second from any direction.	☐	☐
e. The conditions of the sea at the test location shall be calm, and must be of no swell or waves.	☐	☐
3. Vessel		
a. The vessel's draught and trim shall be as near as possible to that of normal operating conditions.	☐	☐
b. The propellers and fuel used for the test shall be the same used for normal operating conditions.	☐	☐
c. Any machinery or equipment driven by the main engine(s) or propeller shaft(s) during normal operations of the vessel must be connected throughout the entire period of the test	☐	☐
4. Test	☐	☐
a. The measured distance between the stern of the vessel and the bollard onshore must be at least 300 meters. This distance is also the length of the hawser used for the test.	☐	☐
b. An adequate two-way voice communication system shall be established between the vessel and the shore station, where the monitoring of the load cell is done.	☐	☐
c. The Continuous Bollard Pull test shall be carried out at the main engine(s)' recommended manufacturer's maximum continuous rating (100% MCR), for a period of 10 minutes, with the vessel maintaining on a fixed course. The value of the continuous bollard pull is then the average reading for the period of 10 minutes.	☐	☐
d. The Maximum Bollard Pull test should then be carried out at the manufacturer's maximum rating (typically 110% MCR) of the main engines, for the period of 5 minutes.	☐	☐
f. An autographic recording instrument giving a continuous read-out and a recording instrument recording the bollard pull graphically as a function of time should be both connected to the load cell. The instruments shall (if possible) be placed and monitored ashore.	☐	☐
g. A torsionmeter shall be installed to correlate the value of shaft power to the value of bollard pull to verify the consistency of the results.	☐	☐
h. The load cell should be fitted between the eye of the hawser and the bollard.	☐	☐
i. The figure certified as the vessel's continuous bollard pull shall be the towing force recorded as being maintained without any tendency to decline for duration of not less than 10 minutes at 100% MCR.	☐	☐

Appendix C

BPTR

Project number: click here to enter a number. certificate number: click here to enter a number.
Choose an item. "Enter Vessel Name."

This is to certify that the undersigned Marine Surveyor did on Click here to enter a date attend the Choose an item. "Enter Vessel Name.", IMO No. Enter IMO number., of Enter Ship Owner(s) as the vessel stay afloat in the Enter Test Venue relative to a BPT and to report as follows:

The vessel's propulsion equipment consists of Enter No. of Engine (s)/Engine Maker. engine(s), Model Enter Model Number. developing a combined output of Enter output in B.H.P.B.H.P (Enter Output in kW. kW) at Enter R.P.M. R.P.M. Each engine drives through a Enter Brand of Propulsion System. Model Enter Model of Propulsion System of Reduction Gear Ratio Enter Reduction Gear Ratio.

At the time of this BPT, there Choose Number of Surveyors. Surveyor(s) (Name of Surveyor) on the Choose Type of Vessel and Choose Number of Surveyors. Surveyor(s) (Name of Surveyor) with the Load Cell Operator.

The BPT was conducted at Start Time/ nd Time hours in the ahead direction and Start Time/End Time hours in the astern direction. The conditions for the bollard pull were as follows:

Environmental conditions		Ship condition	
Wind/Direction	Knots kts/Direction	Draught forward	Click here to enter text. m
Current/Direction	Knots kts/Direction	Draught aft	Click here to enter text. m
Water depth	Click here to enter text. m	Draught amidships	Click here to enter text. m
	Equipment particulars		
Main hawser ength	Click here to enter text. m	Breaking load	Click here to enter text. tonnes
Spare hawser length	Click here to enter text. m	Breaking load	Click here to enter text. tonnes
Winch rated pull	Click here to enter text.	Winch brake	Click here to enter text.

A Model Enter Model of Load Cell with Enter Load Range capacity, calibrated on Click here to enter a date was used. Enter Company for Indicator. provided a computerized indicator with recording/printing capabilities.

It is hereby certified that the vessel under the conditions described over, exerted a **Continuous Bollard Pull** of Enter Bollard Pull tonnes over a minimum period of 10 minutes. It is also certified that the **Maximum Bollard Pull** of Enter Bollard Pull tonnes over a period of 5 minutes.

The BPT was witnessed, and this report prepared without prejudice as to rights and/or interests of whom it may concern.

X

(Surveyor's Fulll Name)

Surveyor

Appendix – D

BOLLARD PULL TEST DATA FORM

Project Number: Click here to enter a number. Certificate Number: Click here to enter a number.

Choose an item. "Enter Vessel Name."

For Surveyor with Load Cell

Bollard Pull Test Location and Personnel Data	
Test Date	Click here to enter a date.
Location	
Vessel Name	
Marine Surveyor	
Others in Attendance	
General Comments	

Load Cell Data	
Load Cell Manufacturer's Name	
Load Cell Model/Type	
Load Cell Last Calibration Date	
Recording Device (Computer)	
Recording Device Manufacturer/Model/Type	
Load Cell Operator's Name and Company	

Comments

Bollard Pull Test Data				
Identify and Highlight the Maximum Pull Sustained for 5 Minutes.				
Time of Day (Hour, Minutes, Seconds)	**Bollard Pull (Tonnes)**			**Mean Pull for Previous 10 Readings**
	Maximum	**Minimum**	**Mean**	
Bollard Pull Test Data				
Time of Day (Hour, Minutes, Seconds)	**Bollard Pull (Tonnes)**			**Mean Pull for Previous 10 Readings**
	Maximum	**Minimum**	**Mean**	

REMARKS

☐	The load cell used for the test *had/had not** been calibrated within the preceding 12 months by a certified testing laboratory. The last certificate was/was not* available for review at time of the bollard pull test.
☐	The load cell *provided/did not provide** a continuous readout.
☐	A device for recording the bollard pull graphically, as a function of the time *was/was not connected** to the load cell.
☐	2-Way voice communication was maintained between the dock and tug during the course of this test.
☐	During the test, there was one Surveyor located in the vessel's engine room and one Surveyor was located on the dock in a position to view the load cell indications.

Surveyor with Load Cell:			
Print Name:			
Company:			

Load Cell Operator:			
Print Name:			
Company:			

Appendix – E

BOLLARD PULL TEST DATA FORM

Project Number: Click here to enter a number. Certificate Number: Click here to enter a number.

Choose an item. “Enter Vessel Name.”

For Surveyor Onboard Vessel

Bollard Pull Test Location and Personnel Data	
Test Date	Click here to enter a date.
Test Location	
Vessel Name	
Marine Surveyor	

Vessel Particulars						
Registered Name	Click here to enter text.					
Official Number	Click here to enter text.					
Port of Registry/Flag	Click here to enter text.					
Year Built/Shipyard	Click here to enter text.					
Classification Society	Click here to enter text.					
Load Line Assigned	Click here to enter text.					
Registered Tonnages	Gross:	Click here to enter text.	Net:	Click here to enter text.		
Length Overall	Click here to enter text.					
Registered Dimensions	Length:	Click here to enter text. m	Breadth:	Click here to enter text. m	Depth:	Click here to enter text. m
Propulsion Plant	Click here to enter text.					
As appropriate, include the following:						
• Number of Main Engines						
• Engine Manufacturer						
• Engine Model Number						
• Continuous BHP Rating @ Specific RPM						
• Number of Gearboxes/Reduction Gears						
• Gearbox Manufacturer						
• Gearbox Model Number						
• Forward/Astern Reduction Ratios						
• Number of Propeller Shafts						
• Number of Main Engines per Shaft						
Propulsion Arrangement	Conventional ☐		Tractor ☐			
Propulsion System Manufacturer	Click here to enter text.					

Propeller(s) used for Test	Diameter:	Click here to enter text. m	Pitch:	Click here to enter text. m	No. of Blades:	

Comments Pertaining to Vessel / Vessel Personnel

Bollard Pull Test Situation				
Water Depth @ Test Site	Click here to enter text. m			
Water Current @ Test Site (Knots)	Click here to enter text. Knots			
Wind Direction / Speed (m/s)	Click here to enter text at Click here to enter text. m/s			
Approximate Air Temperature	Click here to enter text. °c			
Vessel's Drafts	Forward:	Click here to enter text. m	Aft:	Click here to enter text. m
Towing Hawser	Size and Material.			
Hawser Length *(Vessel to Bollard)*	Click here to enter text. m			

Bollard Pull Test - Vessel Operations Data						
Main Engine Data	Port Engine:		Center Engine:		Starboard Engine:	
Max Continuous RPM - Rated/During Test	/		/		/	
Rated Continuous BHP @ Enter RPMRPM						
Over speed RPM Settings						
Max. Lube Oil Pressure/ Temperature	/		/		/	
Max. Cooling Water Temperature	In: °c	Out: °c	In: °c	Out: °c	In: °c	Out: °c
Exhaust Air Temperature	°c		°c		°c	
Reduction Gear Ratio						
Reported Propeller Material						
Reported No. of Propeller Blades						
Reported Propeller Diameter / Pitch						

REMARKS

☐	The test was carried out with the vessel’s trim and/or displacement which correspond to the relevant Load Line requirements and/or Letter of Stability provided.
☐	Auxiliary equipment (i.e., pumps, etc.)
☐	The propellers fitted on the vessel during the test are the same as those reportedly used when the vessel is in normal operation.
☐	Water depth under the keel was twice the vessel’s depth at midship.
☐	Water current did not exceed 1.0 knot.
☐	Wind Speed did not exceed 10 Miles per Hour.
☐	Towline Length was at least twice the length of the vessel from stern/bow to fixed bollard.
☐	2-Way voice communication was maintained between the dock and vessel throughout the entire test.

Surveyor on board the Vessel:			
Print Name:			
Company:			